AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Trip of multiple Cherry Gardens 275 kV and 132 kV lines on 16 July 2021

November 2021

Reviewable Operating Incident Report under the National Electricity Rules

INCIDENT CLASSIFICATIONS

Classification	Detail
Time and date of Incident	2150 hrs on 16 July 2021
Region of incident	South Australia
Affected regions	South Australia
Event type	Environmental – lightning
Generation impact	No generation tripped in response to the event
Customer load impact	No load was shed/disconnected in response to the event

ABBREVIATIONS

Abbreviation	Term
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AEST	Australian Eastern Standard Time
CB	Circuit breaker
CHG	Cherry Gardens
DEF	Directional earth fault
kV	Kilovolt
ms	Milliseconds
MTB	Mount Barker
MTBS	Mount Barker South
NEM	National Electricity Market
NER	National Electricity Rules
s	Seconds
SPAR	Single-phase auto-reclose
TBE	Tailem Bend
TNSP	Transmission network service provider

Important notice

PURPOSE

AEMO has prepared this report in accordance with clause 4.8.15(c) of the National Electricity Rules, using information available as at the date of publication, unless otherwise specified.

DISCLAIMER

AEMO has made every reasonable effort to ensure the quality of the information in this report but cannot guarantee its accuracy or completeness. Any views expressed in this report may be based on information given to AEMO by other persons.

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1. Overview

This report relates to a reviewable operating incident[1] that occurred on 16 July 2021 in South Australia. The incident involved the simultaneous single-phase trip and successful auto-reclose of the 'W'[2] phase of the Cherry Gardens (CHG) – Tailem Bend (TBE) and Cherry Gardens (CHG) – Mount Barker South (MTBS) 275 kilovolt (kV) lines, as well as the three-phase trip of the Mount Barker (MTB) – CHG 132 kV line at the MTB end only.

There was no loss of generation or customer load as a result of this incident.

As this was a reviewable operating incident, AEMO is required to assess the adequacy of the provision and response of facilities and services and the appropriateness of actions taken to restore or maintain power system security[3].

AEMO has concluded that:

1. The simultaneous 'W' phase faults on the CHG – TBE and CHG – MTBS 275 kV lines were caused by lightning.
2. The three-phase trip of the MTB – CHG 132 kV line on the Mount Barker side was caused by unexpected protection operation.
3. The root cause of the unexpected protection operation was the Directional Earth Fault (DEF) protection at Mount Barker identifying DEF in the forward direction/on the protected line due to the unbalanced current flow from the 'W' phase faults on the 275 kV lines. The Cherry Gardens DEF protection initially identified DEF in the reverse direction but reset and therefore did not send a blocking signal to the Mount Barker end, allowing it to trip. ElectraNet[4] has sought manufacturer feedback on the appropriate long-term solution. The manufacturer provided advice on alternative settings to address boundary conditions like those present for this event, which ElectraNet has since evaluated and implemented.
4. The power system remained in a secure operating state throughout this incident.

This report is prepared in accordance with clause 4.8.15(c) of the National Electricity Rules (NER). It is based on information provided by ElectraNet and AEMO.

National Electricity Market time (Australian Eastern Standard Time [AEST]) is used in this report.

2. The incident

2.1 Pre-incident conditions

Prior to the incident, the CHG – TBE and CHG – MTBS 275 kV lines, and the MTB – CHG 132 kV line were all in service. AEMO and ElectraNet were aware of lightning activity in the area of the CHG – TBE and the CHG – MTBS 275 kV lines.

[1] See NER clause 4.8.15(a)(1)(i), as the event relates to a non-credible contingency event; and the AEMC Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.

[2] R-S-T and U-V-W phase sequences are equivalent to A-B-C, R-W-B, or R-Y-B phase sequence. R-S-T are used to denote the phases of 132 kV lines, and U-V-W are used to denote the phases of 275 kV lines.

[3] See NER clause 4.8.15(b).

[4] ElectraNet is the transmission network service provider (TNSP) in South Australia.

In accordance with AEMO's Power System Security Guidelines[5], AEMO was not required to reclassify the simultaneous loss of both lines as a credible contingency, as both lines had no history of three-phase tripping simultaneously due to lightning.

Figure 1 in Appendix Error! Reference source not found. shows which circuit breakers (CBs) tripped during the incident.

2.2 The incident

At 2249 hrs on 16 July 2021, there were simultaneous 'W' phase faults on the CHG – TBE and the CHG – MTBS 275 kV lines. As a result, the 'W' phase of both lines tripped simultaneously. Approximately 500 milliseconds (ms) after the faults on the 275 kV lines were cleared, DEF protection at Mount Barker substation three-phase tripped the Mount Barker CBs for the MTB – CHG 132 kV line. The line remained energised from the Cherry Gardens substation.

Approximately 1 second (s) after the fault, the 'W' phase CBs on both 275 kV lines successfully auto-reclosed to restore both circuits.

At 2205 hrs, the MTB breakers for the MTB – CHG 132 kV line were successfully remotely closed.

2.3 Analysis

The following is based on information provided by ElectraNet.

High voltage phase to ground faults occurred on the 'W' phase conductors of the CHG – TBE and the CHG – MTBS 275 kV lines simultaneously as a result of a lightning strike. The protection systems on the lines operated as expected to clear the fault by tripping only the 'W' phase of CB6714 at Cherry Gardens, CB6682 at Mount Barker South. As per design, CB6715 at Cherry Gardens and CB6680 at Mount Barker South tripped all three phases and did not reclose. CB6714 and CB6682 successfully auto-reclosed on 'W' phase approximately 1 s after fault clearance, re-energising all three phases of both circuits. At 2155 hrs, CB6715 and CB6680 were closed remotely by operators. Two phases of both CHG – TBE and the CHG – MTBS 275 kV lines remained in service throughout the event.

The Weather Zone lightning detection service indicated that there was a lightning strike close to the structure STR356 at 2150 hrs. The Fault Locator estimated that the locations of the faults were at STR366 and STR364. The ground patrol conducted following the incident identified 'W' phase insulator flashovers on both 275 kV circuits at STR359, indicating that this was the location of the faults on both circuits.

ElectraNet has advised that routine transmission line structure earthing testing completed in April 2021 on structures STR352-357 identified a number of defects, including earthing resistances greater than 10 Ohms. Corrective actions were scheduled but have not yet been completed. As a result of this double circuit fault, the testing of further structures on these circuits, including STR359, was also scheduled. No earthing testing results for the STR359 structure are available to date.

The tripping of MTB – CHG 132 kV line CBs (CB6083 and CB6084) at Mount Barker was initiated by the DEF protection at Mount Barker. The line protection at Cherry Gardens did not operate, and the line remained energised from this end. At 2205 hrs, CB6083 and CB6084 at Mount Barker were closed remotely by operators.

The DEF protection on the MTB – CHG 132 kV line operates by detecting the residual or zero-sequence current flowing into the protected line. The direction of the zero-sequence current is determined by comparing the measured current with the voltage signals. DEF protection is configured as a blocking scheme where DEF elements are set in the relays at both ends of the line and signals are sent between them. A trip will occur if a relay detects an earth fault in the forward direction/direction of the protected line and it does not receive a blocking signal from the relay at the remote end of the line. If either relay detects an earth fault

[5] Refer to AEMOs Power System Security Guidelines (SO_OP_37150) Section 8.4.3 for details of the Lightning Detection Zones, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/procedures/so_op_3715-power-system-security-guidelines.pdf?la=en.

in the reverse direction/behind the relay, it sends a blocking signal to the remote end to prevent its DEF element from initiating a trip. Therefore, for correct operation, the relays must send blocking signals when fault current flows through the line to feed an external fault.

For this event, the three phases of the 132 kV line voltages remained balanced, therefore there would not have been a large unbalance voltage signal for the relays to determine the fault direction. ElectraNet confirmed that the relay manufacturer advised that under some boundary conditions, such as those present during this event, the DEF protection could incorrectly determine a fault to be in the forward direction. The manufacturer also recommended alternative settings to address this issue, which ElectraNet has since evaluated, tested and implemented.

3. Power system security

AEMO is responsible for power system security in the NEM. This means AEMO is required to operate the power system in a secure operating state to the extent practicable and take all reasonable actions to return the power system to a secure state following a contingency event in accordance with the NER[6].

The power system was in a secure operating state throughout this incident, and no action was required by AEMO to restore or maintain power system security.

3.1 Reclassification

AEMO assessed whether to reclassify this incident as a credible contingency event[7].

AEMO did not reclassify the loss of both CHG – TBE and the CHG – MTBS 275 kV lines as a single credible contingency. This is because AEMO's Power System Security Guidelines state that any successful simultaneous single phase auto-reclose (SPAR) operation on multiple lines does not require AEMO to reclassify the loss of the multiple lines as a credible contingency[8].

In addition, the MTB – CHG 132 kV line is not classified as a transmission element. As such, AEMO correctly determined that reclassification of this event as a credible contingency event was not required.

4. Market information

AEMO is required by the NER and operating procedures to inform the market about incidents as they progress. This section assesses how AEMO informed the market[9] over the course of this incident.

For this incident, AEMO informed the market on the following matters:

[6] Refer to AEMO's functions in section 49 of the National Electricity Law and the power system security principles in clause 4.2.6 of the NER.

[7] AEMO is required to assess whether or not to reclassify a non-credible contingency event as a credible contingency event – NER clause 4.2.3A(c) – and to report how the reclassification criteria were applied – NER clause 4.8.15(ca).

[8] Transmission system CBs are typically capable of single-phase or three-phase auto-reclose. The auto-reclose function means that after a fault is detected, the breaker will open (either a single phase or all three phases), clearing the fault, and then attempt to reclose again after a specified deadtime/delay. If the fault is still present, the breaker will lockout auto-reclose and remain open. Transient, single-phase faults constitute the majority of faults on high voltage transmission lines. It is therefore common practice to employ single-phase trip and auto-reclose functionality on high voltage transmission lines to minimise the impact of these faults on power system security. The dead time for auto-reclose, in this case, is approximately one second for 275 kV.

[9] AEMO generally informs the market about operating incidents as they progress by issuing Market Notices – see https://www.aemo.com.au/Market-Notices.

1. A non-credible contingency event – notify within two hours of the event[10].
   - AEMO issued Market Notice 88302 at 2321 hrs on 16 July 2021, 92 minutes after the event, to advise of the non-credible contingency event and that the cause had been identified.
   - AEMO issued Market Notice 88303 at 2400 hrs on 16 July 2021 to advise that AEMO had identified the cause of the incident as lightning, and that the Cherry Gardens – Tailem Bend and Cherry Gardens – Mount Barker South 275 kV lines successfully single pole auto-reclosed.

5. Conclusions

AEMO has assessed this incident in accordance with clause 4.8.15(b) of the NER. In particular, AEMO has assessed the adequacy of the provision and response of facilities or services, and the appropriateness of actions taken to restore or maintain power system security.

AEMO has concluded that:

1. The simultaneous 'W' phase faults on the CHG – TBE and CHG – MTBS 275 kV lines were caused by lightning.
2. The trip of the MTB – CHG 132 kV line at the Mount Barker end only was caused by unexpected protection operation.
3. The root cause of the unexpected protection operation was the Directional Earth Fault (DEF) protection at Mount Barker identifying DEF in the forward direction/on the protected line due to the unbalanced current flow from the 'W' phase faults on the 275 kV lines. The Cherry Gardens DEF protection initially identified DEF in the reverse direction but reset and therefore did not send a blocking signal to the Mount Barker end, allowing it to trip. ElectraNet has sought manufacturer feedback on the appropriate long-term solution. The manufacturer provided advice on alternative settings to address boundary conditions like those present for this event, which ElectraNet has since evaluated and implemented.
4. The power system remained in a secure operating state throughout this incident.

6. Recommendations

AEMO recommends that ElectraNet updates the DEF protection settings of other relays in the network in line with the manufacturer's advice to prevent future similar maloperations.

It is also recommended that ElectraNet notifies AEMO if it is believed that there is an increased risk of equipment tripping due to high footing resistance during abnormal conditions in accordance with Clause 4.2.3. Classification as an abnormal condition allows AEMO to take additional measures to manage power system security if required.

Additionally, following the earthing testing being completed on the structures for these lines, corrective actions should be implemented to reduce earthing resistance in order to prevent future trips due to lightning.

[10] AEMO is required to notify the market of a non-credible contingency event within two hours of the event – AEMO, Power System Security Guidelines, Section 7.3.

A1. System diagram

The diagram below provides an overview of part of the power system immediately after fault clearance.

Figure 1 State of the system following fault clearance